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1 **Reliability of the 505 Change of Direction Test in Netball Players**

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43 **Abstract**

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45 **Purpose:** To determine the reliability of the 505 change of direction (COD) test performed
46 with both a stationary and flying start. **Methods:** Fifty-two female netball players (age $23.9 \pm$
47 5.4 yrs, height 169.9 ± 3.3 cm, body mass 65.2 ± 4.6 kg) performed 6 trials of the 505 COD
48 test, three with a flying start and three with a stationary start, once per week over a four week
49 period, to determine within- and between-session reliability. **Results:** Testing revealed high
50 within-session reliability for the stationary start (ICC = 0.96-0.97) and for the flying start
51 (ICC = 0.90-0.97). Similarly, both the stationary start (ICC = 0.965) and the flying start
52 demonstrated high reliability (ICC = 0.951) between-sessions, although repeated measures
53 analysis of variance ($p < 0.001$) revealed learning effects were found to be present between-
54 sessions for both tests. Performances stabilized on the second day for the static start and on
55 the third day of testing for the flying start. **Conclusions:** Results suggest that the 505 COD
56 test is a reliable test in female netball players, with either a stationary or flying start. Smallest
57 detectable differences of 3.91% and 3.97% for the stationary start and the flying start,
58 respectively, allow practitioners to interpret whether changes in time taken to complete the
59 505 COD test reflect genuine improvements in performance or are measurement errors. It is
60 suggested that one day of familiarization testing is performed for the stationary start and two
61 days of familiarization for the flying start, to minimize learning effects.

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70 **Key Words:** Agility; Learning affects; Smallest Detectable Difference; Meaningful

71 Difference

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76 **Introduction**

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78 The importance of change of direction (COD) and agility has been highlighted in many team
79 sports, including football, ¹ rugby, ² basketball, ³ volleyball, ⁴ and netball. ⁵⁻⁸ Emphasising
80 high speed movements may only contribute to a low percentage of match distance covered,
81 but they are crucial to many match winning situations, such as gaining possession and
82 preventing or creating scoring opportunities. ^{1, 7, 8} During elite netball matches in particular,
83 athletes can perform up to 81.3 ± 20.1 high-intensity sprints ⁶ and 63.7 ± 7.6 COD
84 maneuvers,⁵ which highlights the importance of these tasks to competitive netball
85 performance and warrants the inclusion of agility/COD assessments within netball
86 performance testing batteries. Agility tests are widely used within sports testing batteries to
87 establish an athlete's ability to rapidly change direction. ^{3, 9} Although many tests are referred
88 to as agility tests, they are usually methods of assessing COD performance, as agility includes
89 a reaction to a stimulus, which is not part of the majority of these tests. ⁹ Many COD tests,
90 such as the Illinois agility run, 505 COD test and T-Test, attempt to mimic common
91 movement patterns performed within a given sport, ¹⁰ however, few studies have investigated
92 the reliability of these tests.^{2, 11, 12} Reliability of methods of assessment is highly important to
93 ensure that sports scientists and researchers can appropriately interpret changes in
94 performance as being meaningful or a product of the error inherent within the testing
95 procedures adopted.

96

97 Research has reported that within-session learning effects are present during COD t-tests, but
98 this stabilizes after only one trial.¹¹ The 505 COD test has also been shown to yield a reliable
99 measure of COD amongst female softball players, with a high test-retest reliability (intra-
100 class correlation coefficient (ICC) ≥ 0.93), ¹² although learning effects were not reported.

101 Typically, the protocol for the 505 COD test allows a ten meter run up (flying start) before
102 crossing the start line and timing commencing. Although the reliability of the 505 COD test
103 has been investigated previously,¹² no studies have specifically assessed female netball
104 players or compared the reliability of stationary and flying starts, or reported the potential
105 learning affects during both tests. Identification of any systematic learning effects are
106 essential to ensure that sports scientists and researchers apply appropriate methods when
107 collecting baseline data, to ensure that any subsequent changes in performance are
108 meaningful and are not due to learning effects.

109

110 The purpose of this study, therefore, was to assess the within- and between-session reliability
111 of the 505 COD test performed with both stationary and flying (ten meter approach) starts. It
112 was hypothesized that both tests would demonstrate a learning effect, with improved
113 performances between the initial sessions; and that the stationary start for the 505 COD test
114 would be the most reliable as it is easier to standardize. A further aim was to identify the
115 smallest detectable differences in performances between-sessions to aid practitioners in
116 determining meaningful changes in 505 COD test performances.

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118

119 **Methods**

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121 *Experimental Design*

122 This study assessed the within- and between-session reliability of the 505 COD test to
123 identify the magnitude of difference which reveals a meaningful change in performance. A
124 secondary aim was to determine if learning effects were present in trained female netball
125 players who had no previous experience of performing the 505 COD test. Previous studies

126 have typically assessed the between-session reliability of COD tests over two to three
127 sessions^{11, 13} and have indicated that the magnitude of observed learning effects is dependent
128 upon both the number of trials and the task being performed. The COD tests included in the
129 present study were, therefore, completed on the same day each week for four weeks, at the
130 same time of day (19:00-20:00), where subjects performed six repetitions of the 505 COD
131 test; three with a flying start and three with a stationary start. The same researcher and the
132 coaching staff were present at all sessions to ensure that a similar level of athlete motivation
133 was achieved between-sessions. This approach allowed within- and between-session
134 reliability and measurement error to be calculated and learning effects to be determined.
135 Within-session reliability was determined using the ICC, standard error of measurement
136 (SEM), smallest detectable difference (SDD), and 95% confidence intervals. Repeated-
137 measures analysis of variance (RMANOVA) was used to assess between-session reliability
138 and learning effects.

139

140 *Subjects*

141 Fifty-two female players (age 23.9 ± 5.4 yrs, height 169.9 ± 3.3 cm, body mass 65.2 ± 4.6
142 kg, average playing experience 14.8 ± 4.9 yrs) volunteered to participate in this study. All
143 subjects were injury free and had \geq five years experience of playing netball for a minimum of
144 one hour \geq two x week. All participants provided written informed consent to participate, and
145 the University of Salford Research and Ethics Committee approved the research and
146 conformed to the *Code of Ethics of the World Medical Association* (Declaration of Helsinki).

147

148 *Procedures*

149 The 505 COD test requires subjects to sprint five meters, turn 180° and sprint a further five
150 meters (Figure 1). A 'flying start' allowed the subject a 10 m run up before crossing the start

151 line and timing commenced. A ‘stationary start’ required a static start position 0.5 m behind
152 the start line, to prevent early triggering of the timing gates. Subjects were asked to plant their
153 dominant foot upon executing the turn.

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156 [***Insert Figure 1 here***]

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159 Testing took place once a week, at the same day and time (19:00-20:00), on the same netball
160 court, for four weeks, at the start of the competitive season. After a standardized progressive
161 warm up, participants performed three timed attempts with both stationary and flying starts
162 (six trials in total, per session). All times were recorded using Brower timing gates (Brower,
163 Speed Trap 2 Wireless Timing System, UT, USA) extended to approximately hip height. The
164 time started when a participant first passed through the timing gates and stopped when the
165 participant passed through them again upon their return. One minute of recovery time was
166 given between each attempt, with a three minute rest period prescribed between the flying
167 and static starts. Participants were requested to standardize their dietary intake during each
168 day of testing and to avoid strenuous exercise for the 48 hours prior to testing.

169

170 *Statistical Analyses*

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172 Statistical analysis was performed using SPSS version 20.0 (IBM, USA). Descriptive
173 statistics (mean, standard deviation (SD) and 95% confidence intervals) were calculated for
174 time to complete the 505 COD test. Within-session reliability was determined using the ICC,
175 and interpreted following the criteria of: Poor = 0.40; Fair = 0.40–0.70; Good = 0.70–0.90;

176 and Excellent = 0.90.¹⁴ Between-session reliability was determined, using the best
177 performances from each day, via ICCs and two separate (static and flying 505 COD tests)
178 repeated measures ANOVA (RMANOVA), with Bonferroni post hoc analysis. An a priori
179 alpha level was set at $p \leq 0.05$. Effect sizes were also measured using partial Eta squared, to
180 determine the magnitude of difference between days, and interpreted according to the Cohen
181 *d* method,¹⁵ which defines 0.2, 0.5, and 0.8 as small, medium and large, respectively. The
182 SEM was calculated from the formula $((SD(\text{pooled}) \times (\sqrt{1-ICC}))$, and the SDD was
183 calculated using the formula $(1.96 \times \sqrt{2}) \text{ SEM}$.¹¹

184

185 **Results**

186 *Within-Session Reliability*

187 The ICCs for both the stationary 505 (0.96-0.97) and flying 505 (0.90-0.97) showed excellent
188 within-session reliability (Table 1).

189

190 *Between-Session Reliability and Learning affects*

191 The ICCs for both the stationary 505 (0.968) and flying 505 (0.951) also showed excellent
192 reliability between-sessions. The RMANOVA identified significant differences between days
193 for the stationary start [$F_{(3,153)} = 9.031, p < 0.001, \eta = 0.22, \text{power } 0.96$], with Bonferroni post-
194 hoc analysis identifying that 505 performances from a static start on days two, three and four
195 were significantly faster (2.84 ± 0.22 s, 2.84 ± 0.23 s, 2.82 ± 0.22 s, $p \leq 0.01$, respectively)
196 when compared to day one (2.88 ± 0.23 s). There were no significant differences ($p > 0.05$)
197 between days two, three or four (Table 1).

198

199 Similarly, there was a significant difference between days for the 505 performed with a flying
200 start [$F_{(3,153)} = 2.319, p < 0.01, \eta = 0.04, \text{power } 0.95$], with post-hoc analysis for the flying 505

201 identifying significantly faster performances on days three and four (2.54 ± 0.16 s, $2.52 \pm$
202 0.17 s, $p \leq 0.01$, respectively) compared to day one (2.57 ± 0.18 s). There were no additional
203 significant differences ($p > 0.05$) between testing days (Table 1).

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206 [***Insert Table 1 about here***]

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208

209 **Discussion**

210

211 The results of this study demonstrated a high within-session and between-session reliability
212 ($ICC \geq 0.899$) for both versions of the 505 COD test; however, both tests did demonstrate
213 learning effects between-sessions, in line with our hypotheses. Performance in the 505
214 performed with a static start stabilizes after one day of familiarization, whereas the flying 505
215 appears to stabilize after two days of familiarization in female netball players.

216

217 The administration of COD testing, in particular the 505 COD test, is popular in team-sports
218 ^{12, 16, 17}; however, it is important that the 505 COD test demonstrates high reliability so results
219 can be interpreted appropriately. Therefore, practitioners should be aware of the learning
220 effects of each test. Within-session reliability of the 505 COD test demonstrated excellent
221 reliability ($ICC = 0.959-0.974$), with the exception of the flying start on day one which only
222 demonstrated a good reliability score ($ICC = 0.899$). A previous study also investigating
223 female athletes reported similar reliability ($ICC = 0.92$), in line with our findings.¹²

224

225 There was evidence of a learning effect with significant differences ($p < 0.001$) present
226 between testing sessions for the stationary start and flying start. With a stationary start, days
227 two, three and four all resulted in small but significantly ($p < 0.01$) faster times compared to
228 day one, although there were no differences between days two, three and four. These results
229 demonstrate that only one day of familiarization is required for performances to stabilize
230 during the 505 COD test performed from a stationary start. In addition, with a flying start, the
231 only significant differences ($p < 0.01$) were found between day one and days three and four,

232 with no significant difference ($p>0.05$) between days three and four, highlighting that
233 performances stabilized after two days of familiarization for the flying 505 COD test. It can
234 be concluded, therefore, that the 505 COD test is a reliable test, when performed with either a
235 stationary or flying start, although some familiarization is required. The difference in
236 familiarization required between the stationary start and the flying start may be attributable to
237 the fact that running velocity and therefore momentum is likely to be higher during the flying
238 start. The flying start also adds the potential for additional variability in the approach velocity
239 and therefore slightly reduces the reliability of the test. It is suggested that future research
240 determine the variability and effect of approach speed on the reliability and performance in
241 the flying 505 COD test.

242

243 The presence of learning effects during the administration of the 505 COD test, for both
244 stationary and flying starts highlights the need for practice trials to be administered before
245 testing, to ensure the most reliable outcome is achieved. We suggest two practice trials are
246 adequate, as followed in the aforementioned protocol. The excellent to good ICC scores
247 allow coaches to administer the 505 COD test female netball players with confidence. Munro
248 and Herrington ¹¹ explain that SEM values show the range in which an individual's true score
249 is likely to lie, whereas SDD values allow practitioners to interpret whether a change in an
250 individual's performance is significant. The SEM and SDD values gained from this research
251 will allow coaches to evaluate true changes in performance and eliminate measurement error
252 as a cause of change. With a base of raw data being collected, if the same protocol is
253 followed, comparisons across netball teams and between players will be made easier.

254

255 No studies, to our knowledge, have presented the SEM and SDD values for the 505 COD
256 test, using female participants. With no statistical evidence providing measurement error
257 values it is difficult for coaches to identify meaningful improvements, however this study
258 demonstrates that changes of $\geq 3.91\%$ and $\geq 3.97\%$ for the stationary start and the flying start,
259 respectively, in female netball players, are meaningful. It should be acknowledged that COD
260 was only assessed for the dominant leg in this study and therefore reliability and learning
261 effects of the 505 COD test using the non-dominant leg may be more varied. Previous
262 research showed that flying 505 COD times of elite female softball players decreased by
263 5.48% ($p=0.03$) for the non-dominant leg and by 1.09% ($p>0.05$) for dominant leg across a
264 competitive season.¹⁸ When applying the results of the present study to the aforementioned
265 data, it can be reasoned that the change in flying 505 COD performance noted for the

266 dominant leg was not meaningful which is line with the reported effect size ($d = 0.43$). It is
267 suggested that future research should compare performances, reliability and learning effects
268 of the 505 COD test variations between limbs in order to establish what a meaningful change
269 in the performance of these tasks with the non-dominant is for future studies and to allow for
270 a more accurate interpretation of previous findings.

271

272

273 *Practical Applications*

274 It is recommended that strength and conditioning coaches ensure appropriate familiarization
275 with the 505 COD test prior to testing athletes, consisting of one familiarization session for
276 the 505 COD performed with a stationary start and two familiarizations sessions if performed
277 with a flying start. Additionally, differences in 505 COD times of $\geq 3.91\%$ and $\geq 3.97\%$ for the
278 stationary start and the flying start, respectively, in female netball players, highlight
279 meaningful changes. Future research should seek to determine if the level of reliability and
280 learning effects are similar in other team sports.

281

282

283 *Conclusion*

284 The results of this study demonstrate a high within-session and between-session reliability for
285 both versions of the 505 COD test. Both tests do, however, demonstrate learning effects
286 between-sessions. Performance in the 505 performed with a static start stabilizes after one
287 day of familiarization, whereas the flying 505 appears to stabilize after two days of
288 familiarization, however, it should be noted that these changes between-sessions, while
289 statistically significant, were small.

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296

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393 **Table and Figure Legends**

394 Table.1. Comparison of performances (Means \pm SD, 95% Confidence Intervals) and
 395 reliability statistics (ICC, SEM and SDD) across days

Trial Day	Mean \pmSD (s)	95% CI	ICC	SEM	SDD (s)
Stationary 1	2.88 \pm 0.23	2.80-2.93	0.959	0.05	0.130 (4.51%)
Stationary 2	2.84 \pm 0.22*	2.77-2.89	0.969	0.04	0.105 (3.00%)
Stationary 3	2.84 \pm 0.23*	2.77-2.90	0.971	0.04	0.105 (3.00%)
Stationary 4	2.82 \pm 0.22*	2.75-2.88	0.973	0.04	0.100 (3.55%)
Mean	2.84 \pm 0.22	2.78-2.90	0.968	0.04	0.111 (3.91%)
Flying 1	2.57 \pm 0.18	2.51-2.61	0.899	0.06	0.16 (6.23%)
Flying 2	2.55 \pm 0.17	2.50-2.59	0.974	0.03	0.08 (3.14%)
Flying 3	2.54 \pm 0.18*	2.49-2.59	0.963	0.04	0.10 (3.94%)
Flying 4	2.52 \pm 0.16*	2.47-2.56	0.966	0.03	0.08 (3.17%)
Mean	2.52 \pm 0.17	2.48-2.56	0.951	0.04	0.10 (3.97%)

*Significantly different from Day 1 (p \leq 0.01)

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